Description of Analytical Tools

Name: Simulation of Evapotranspiration of Applied Water (SIMETAW)

Author: California Department of Water Resources (Morteza N. Orang and J. Scott Matyac, Division of Planning and Local Assistance) and the University of California, Davis (Richard L. Snyder, Department of Land, Air and Water Resources, Shu Geng, Dept. of Agronomy and Range Science, Davis, CA, and Sara Sarreshteh, Department of Land, Air and Water Resources)

Availability of Technical Support: A summary of SIMETAW documentation is available on DWR web site:
(http://www.landwateruse.water.ca.gov/basicdata/agwateruse/cropmodels.cfm)

Categories: Weather Simulation and ET of Applied Water Estimation for Crops

Main Features and Capabilities:

1 Daily time step calculations.
2 Simulation of daily weather data from monthly means for a specified number of years. Weather variables include solar radiation, maximum and minimum temperature, wind speed, dew point temperature, and rainfall.
3 May be used as a tool to fill in missing data points where only monthly mean weather data exist.
4 Allows one to investigate how changes in weather will affect the water demand in the state (climate change study).
5 Simulation of daily reference evapotranspiration (ET_o) data directly from monthly means of ET_o and pan evaporation data.
6 Calculations of daily ET_o from either raw or simulated daily weather data for the period of record.
7 Employs the latest methodology to estimate daily crop coefficients for estimating crop evapotranspiration.
8 Adjusts crop coefficients for wetting frequency from rainfall or irrigation during the off season.
9 Accounts for cover crop and immaturity effects on crop coefficients for tree and vine crops.
10 Daily calculations of crop coefficients and crop evapotranspiration.
11 Daily calculations of effective rainfall based on soil water depletion and rainfall amounts.
12 Generates hypothetical irrigation schedules to determine ET of applied water (ET_{aw}) for crops within a study area for the period of record.
13 Spatial scale at *DAU and county levels*
14 Outputs years of raw or simulated daily weather and calculated ET_o data by weather station.

15 Outputs means of weather data and rainfall for each day of the year averaged over the period of record.
16 Shows daily and monthly water balance statistics over the years of record.
17 Outputs monthly means of ET_o, ET_c, Pcp, effective rainfall and ET_{aw} averaged over the years of record for a specified study area
18 Contains in-saeson ET_c, effective rainfall, and ET_{aw}, annual cumulative ET_c, effective rainfall, and ET_{aw}, and the cumulative off-season ET_c, effective rainfall, and ET_{aw} files for each year of record for a specified study area.
19 The SIMETAW model is designed to use weather, temperature, ET_o and pan evaporation data to make water balance calculations without changing the model code.
20 SIMETAW is written in the Borland C^{++} builder language and runs on IBM PC compatible-equivalent or higher, 16MB RAM, Windows 95/98, NT 4.0, Windows 2000, Windows XP. It is available in CD.

Applications: The model so far has been applied to Davis, Oceanside, and Bishop in California to evaluate its performance at sites influenced by coastal and windy desert climates. SIMETAW will also be applied to the Delta Uplands and Lowlands to make water balance calculations for the period of 1921 to 1998 to improve their historical estimates of ET of applied water reliability.

Calibration/Validation/Sensitivity Analysis: SIMETAW is designed to estimate ET_{aw} for a well drained soil type fields. It estimates daily effective rainfall based on soil water depletion and rainfall amounts. Because the water balance is calculated each day, rainfall water losses due to surface runoff can be ignored. Since the rice fields are flooded and deep percolation is minimal, SIMETAW was adjusted to assume that most rainfall to a rice paddy is effective. The Hargreaves-Samani (H-S) equation used by SIMETAW for computing ET_o must be calibrated for sites influenced by coastal and windy climates, otherwise it may over- or under-estimate ET_o values for a region of interest. To validate the simulation part of the program, nine years of daily measured weather data (1990–1998) from the California Irrigation Management Information System (CIMIS) in Davis were used in the model to simulate 30 years of daily weather data. The weather data simulated from SIMETAW were compared with the data from CIMIS. Figures 1, 2, and 3 shows that R_s, T_{max}, and rainfall values predicted from SIMETAW were well correlated with those values obtained from CIMIS. Similar results were observed for T_{min}, wind speed, and T_{dew} data. We also compared SIMETAW predictions of ET_o with number of years of estimated daily ET_o data from CIMIS at Davis, Oceanside, and Bishop. The performance of our model ET_o predictions was evaluated at sites influenced by coastal and windy desert climates. Figures 4, 5, and 6 compare daily mean ET_o estimates of SIMETAW and CIMIS averaged over the period of records. The results show a close agreement between CIMIS-based estimates of ET_o and those of the SIMETAW model. Sensitivity analysis has not yet been performed in SIMETAW. We can increase or decrease solar radiation by a factor or change temperature data to see what would happen to the ET_o data. We can also change the rainfall patterns to see what would happen to the ET of applied water.

Figure 1.
Comparison of Measured and Simulated Daily Solar Radiation Data at Davis, California

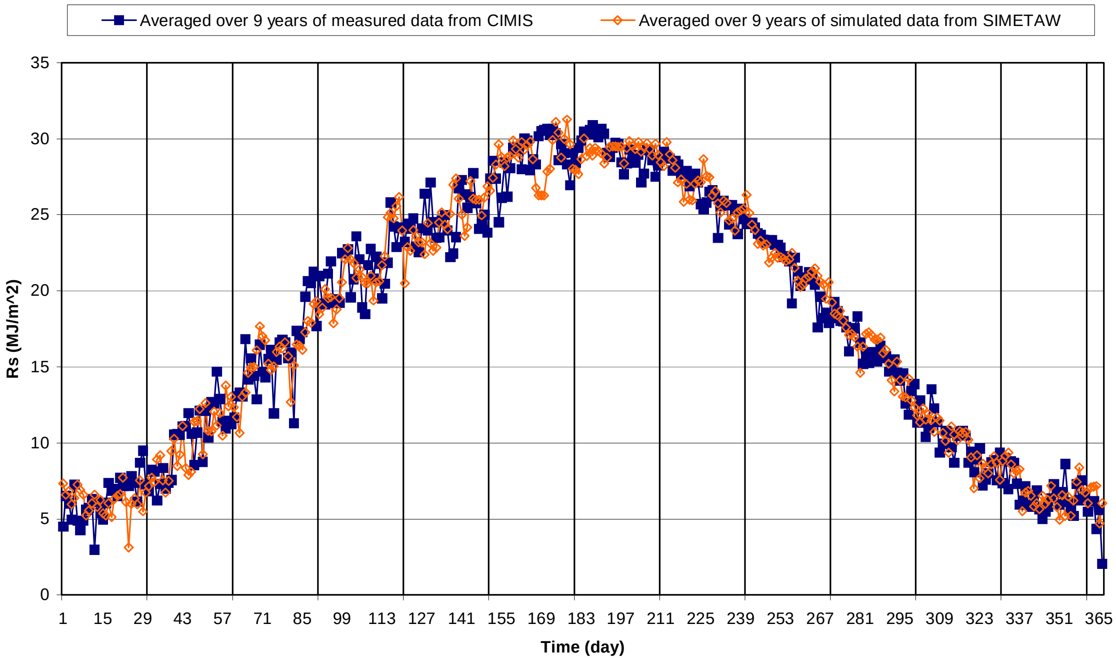
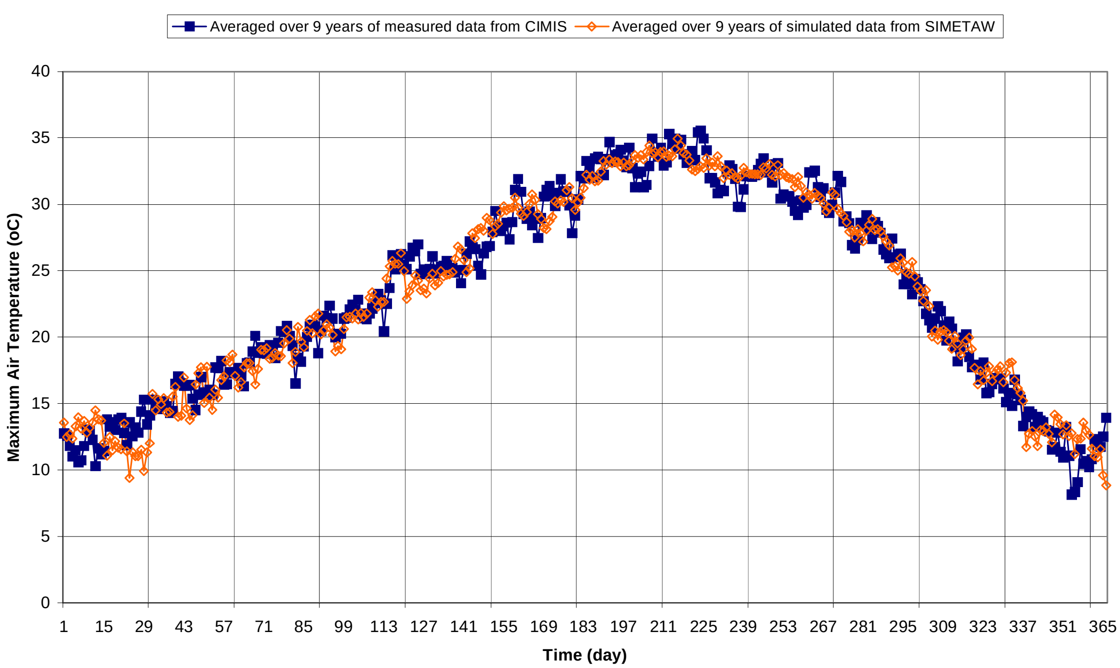


Figure 2
Comparison of Measured and Simulated Maximum Air Temperaure Data at Davis, California



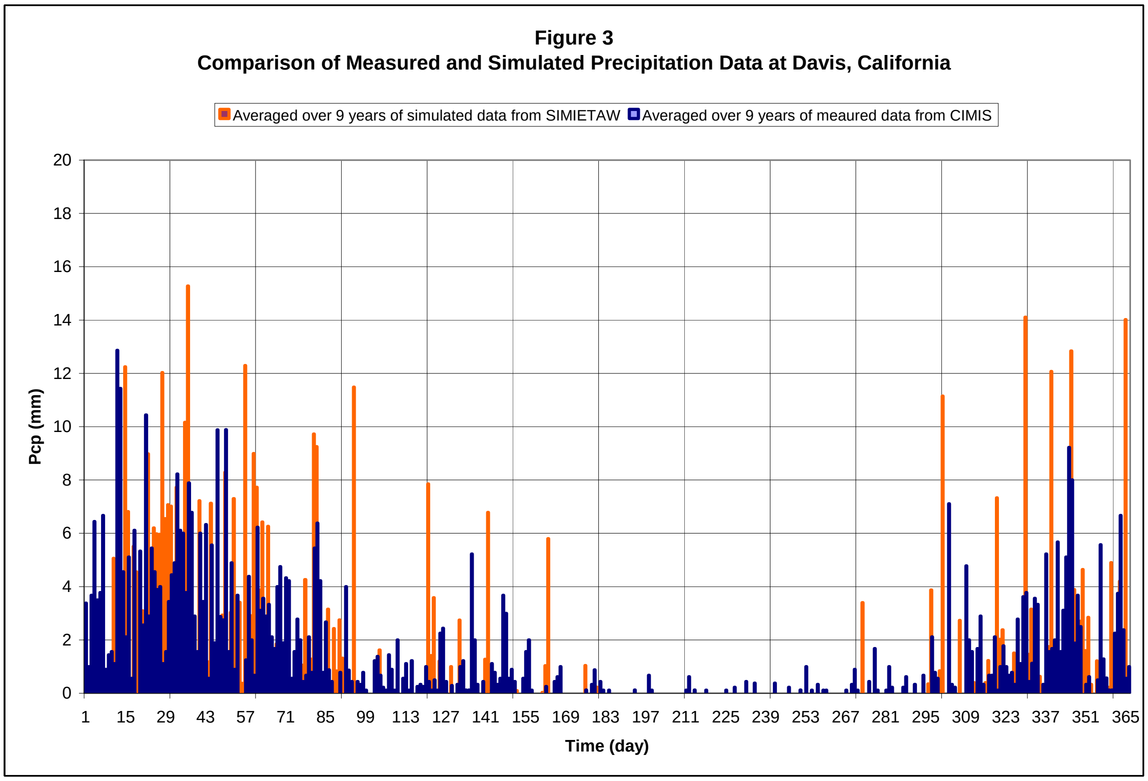


Figure 3
Comparison of Measured and Simulated Precipitation Data at Davis, California
Averaged over 9 years of simulated data from SIMIETAW
Averaged over 9 years of meaured data from CIMIS
Pcp (mm)
Time (day)

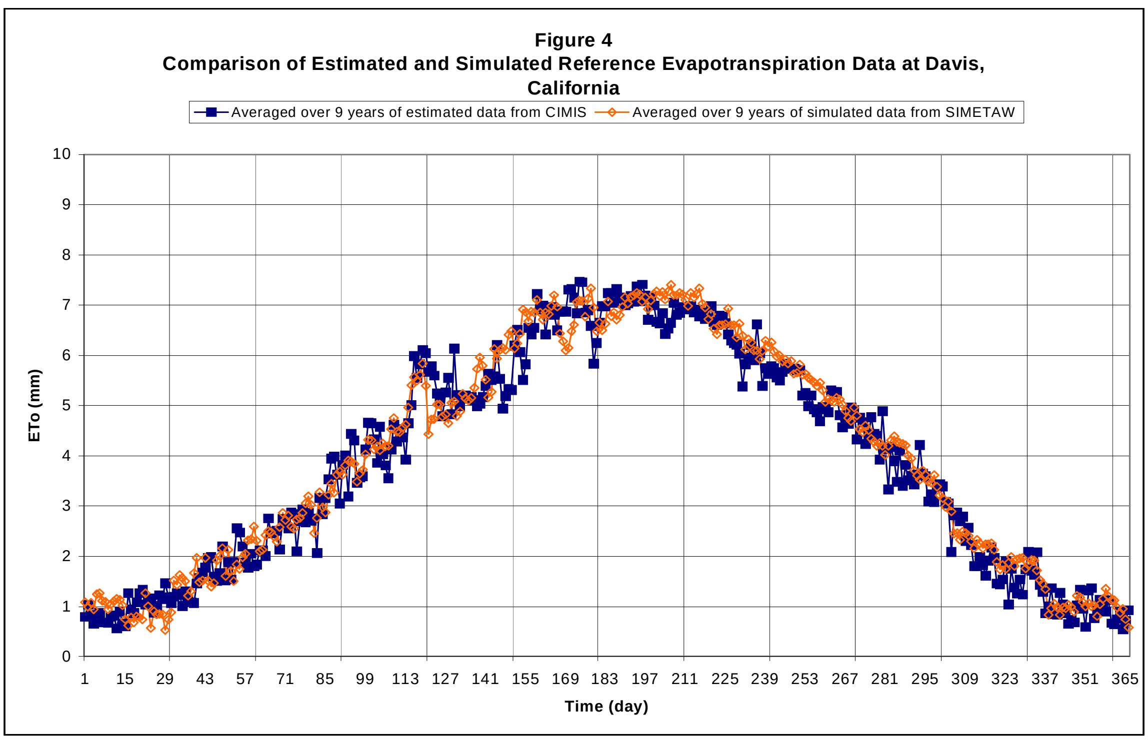
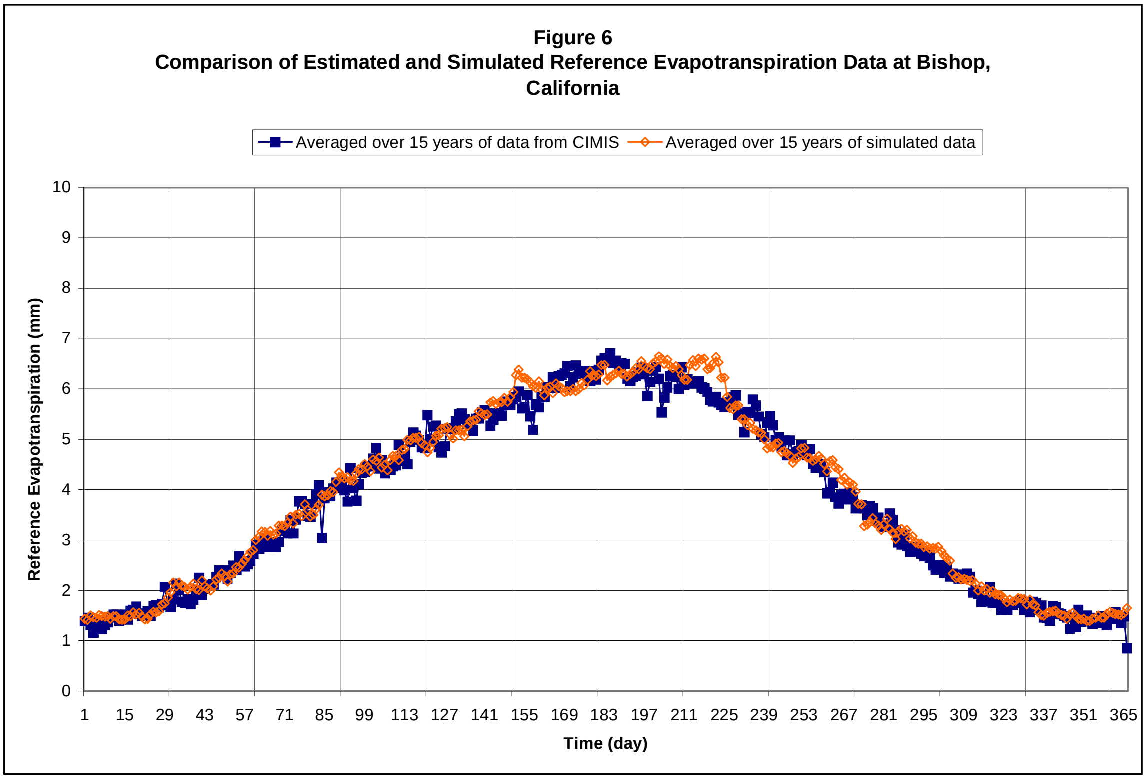


Figure 4
Comparison of Estimated and Simulated Reference Evapotranspiration Data at Davis, California
Averaged over 9 years of estimated data from CIMIS
Averaged over 9 years of simulated data from SIMETAW
ETo (mm)
Time (day)



Peer Review: No formal peer review yet.

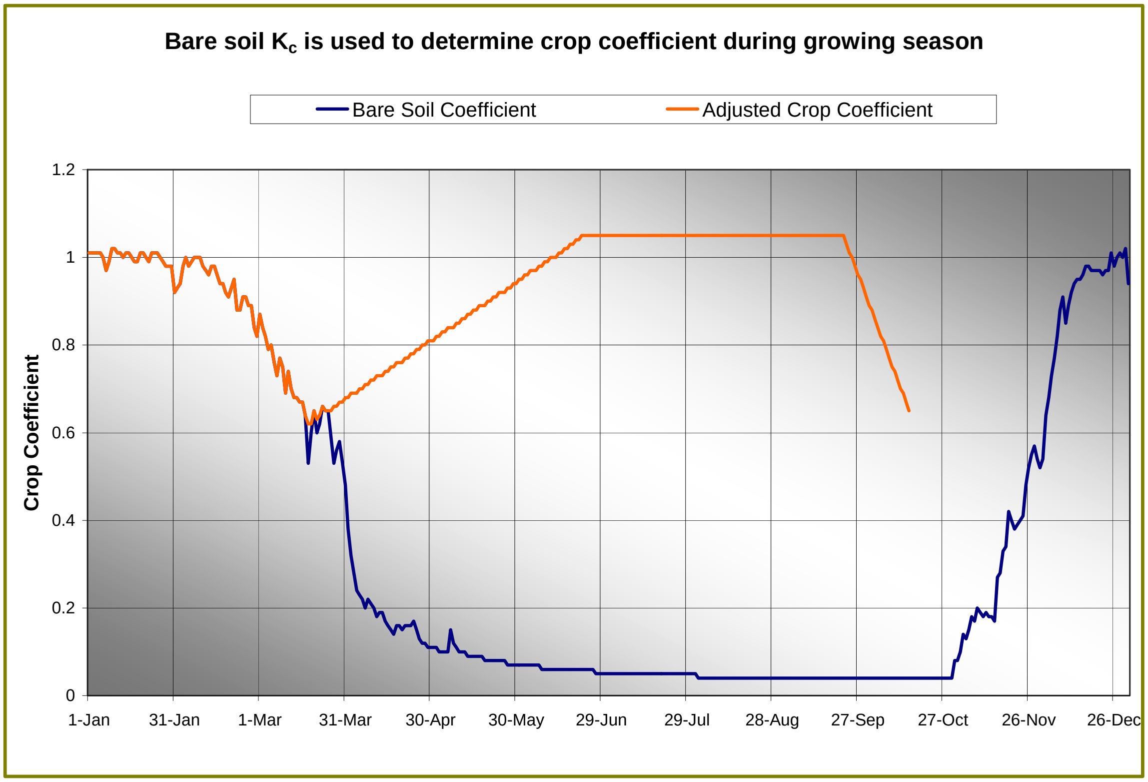
<u>Anatomy of SIMETAW</u>:

-Conceptual Basis: The primary objective of SIMETAW is to simulate daily weather data from monthly climate data and estimates reference evapotranspiration (ET_o) and crop evapotranspiration (ET_c) with the simulated data. In addition, simulated daily rainfall, soil water holding charactersistics, effective rooting depths, and ET_c are used to determine effective rainfall and to generate hypothetical irrigation schedules to estimate the seasonal and annual evapotranspiration of applied water (ET_{aw}), where ET_{aw} is an estimate of the crop evapotranspiration minus any water supplied by effective rainfall. SIMETAW allows one to investigate how climate change may affect water demand in California. All ET_{aw} calculations are done on a daily basis, so the estimation of effective rainfall and, hence, ET_{aw} is greatly improved over earlier methods. In addition, the use of the widely adopted Penman-Monteith equation for reference evapotranspiration (ET_o) and improved methodology to apply crop coefficients for estimating crop evapotranspiration is used to improve ET_{aw} accuracy.

-Theoretical Basis: The theoretical basis of SIMETAW is to use a weather simulation model in conjunction with other models to evaluate possible crop responses to environmental conditions. One important response is crop evapotranspiration (ET_c). Crop evapotranspiration is commonly estimated by multiplying reference evapotranspiration by a crop coefficient. In SIMETAW, daily data are used to estimate reference evapotranspiration. Rainfall data are then used with estimates of ET_c to determine ET_{aw}. One can either use raw or simulated daily data for the calculations. While reference crop evapotranspiration (ET_o) accounts for variations in weather and offers a measure of the "evaporative demand" of the atmosphere, crop coefficients account for the difference between the crop evapotranspiration and ET_o. The main factors affecting the difference are (1) light absorption by the canopy, (2) canopy roughness, which affects turbulence, (3) crop physiology, (4) leaf age, and (5) surface wetness. During early growth of crops, when considerable soil is exposed to solar radiation, ET_c is dominated by soil evaporation and the rate depends on whether or not the soil surface is wet. If a nearly bare-soil surface is wet, the ET_c rate is slightly higher than ET_o, when evaporative demand is low, but it will fall to about 80 percent of ET_o under high evaporation conditions. However, as a soil surface dries off, the evaporation rate decreases considerably. As a canopy develops, solar radiation (or light) interception by the foliage increases and transpiration rather than soil evaporation dominates ET_c. Assuming there is no transpiration-reducing water stress, light interception by the crop canopy is the main factor determining the ET_c rate. Therefore, crop coefficients for field and row crops generally increase until the canopy ground cover reaches about 75 percent. For tree and vine crops the peak K_c is reached when the canopy has reached about 70 percent ground cover. The difference between the crop types results because the light interception is somewhat higher for the taller crops.

-Numerical Basis: In SIMETAW, either daily or monthly climate data are used to determine ET_{aw}. Daily data can come from CIMIS or from a non-CIMIS data source as long as data are in the correct format. After reading the data, ET_{aw} can be calculated directly from the raw daily data. In addition, the monthly means can be used to generate daily weather data for a specified period of record using the simulation program. Daily climate data consist of daily solar radiation, maximum, minimum, and dew point temperature and wind speed for calculating daily ET_o. After calculating ET_o, if the data were generated, the program sorts the rainfall data within each month to force a negative correlation between rainfall amount and ET_o rate. Only the rainfall dates are sorted, and there is no change in the dates for the weather and ET_o data. Furthermore, the program can simulate daily ET_o data directly from monthly means of ET_o and E_{pan} data. Then crop and soil information are used to calculate daily crop coefficients, crop evapotranspiration, effective rainfall, and ET_{aw} for crops within a study area for the period of record.

During the off-season and during initial crop growth, soil evaporation (E) is the main component of ET. Therefore, a two-stage soil evaporation model is used in SIMETAW to estimate bare-soil crop coefficients as a function of mean ET_o and wetting frequency in days. Then, estimated bare soil coefficient values are used as a base line to adjust crop coefficient values for wetting frequency from rainfall or irrigation during the initial growth period. Figure below shows basic concept of crop coefficient adjustment for wetting frequency from rainfall in SIMETAW.



SIMETAW accounts for immaturity effects on crop coefficients for tree and vine crops. Immature deciduous tree and vine crops use less water than mature crops. For tree and vine crops the peak K_c is reached when the canopy has reached about 70 percent ground cover. The program adjusts the mature K_c values (K_{cm}) as a function of percentage ground cover (C_g).
SIMETAW also accounts for cover crop contribution to crop coefficient values for tree and vine crop. With a cover crop, the K_c values for deciduous trees and vines are higher. When a cover crop is present, 0.35 is added to the clean-cultivated K_c. However, the K_c value is not allowed to exceed 1.15 or to fall below 0.90.

-Input and Output: Either daily mean weather data by month or raw weather data can be used in SIMETAW for the calculations of ET_o. Weather data include, solar radiation, maximum and minimum temperature, dew point temperature and wind speed. The program allows for input of daily mean of ET_o and rainfall data by month or daily mean evaporation pan and rainfall data by month. If pan data are input, then the program automatically estimates daily ET_o rates using a fetch value (i.e. upwind distance of grass around the pan) without the need for wind speed and relative humidity data. If daily raw weather data are used, then SIMETAW calculates ET_o directly from the raw data. To run the application to determine ET_{aw} within a study area, it is also required to enter the crop and soil information. The input data include as following:

- A 5-digit Study Area number (1-99999)
- Crop name
- Planting date

- Ending date
- Soil type
- Acreage planted
- Maximum soil depth in inches (depth to hard pan or rock)
- Maximum effective rooting depth during growing season (in)
- Allowable depletion (%)
- Pre-irrigation (Y/N)
- Initial growth wetting frequency
- Ground cover percentage on date B, C, D, and E, which are used to account for immaturity effect on K_c values for tree and vine crops.
- Cover crop dates
- Stress factor, (K_s)

Files created by SIMETAW are listed as following:

- Number of years of raw or simulated daily weather data including calculated ET_o from raw or simulated data by weather station
- Number of years of daily calculated crop coefficients, crop evapotranspiration and water balance calculations by crop within a study area
- One year of simulated or non-simulated daily and monthly ET_c and ET_{aw} data averaged over the data set
- Number of years of simulated or non-simulated seasonal and annual total of ET_c and ET_{aw} by crop within a study area
- Simulated or non-simulated seasonal and annual total of ET_c and ET_{aw} averaged over the years of record.

Data Management: Excel and Word software are used to extract input and output data files from SIMETAW. It allows input of weather, ET_o, and pan evaporation data for calculating crop evapotranpiration and ET of applied water. It includes a large database of climate data from CIMIS for easy input. It allows easy input of crop and soil information. It gives the user the opportunity to view the output values as they are created. Results from the model are exported in Excel and Word file format. All input data files must save as a comma delimited csv file where the SIMETAW program is. Files created by SIMETAW are automatically stored in the directory where the SIMETAW program resides. In the SIMETAW model, all weather data files have a five-character filename with a three-character file extension. The three character extensions and the format for data files depend on the types of data. There are ten possible ways to create input weather data files for the SIMETAW program.

Software: The SIMETAW application program was written in Borland Professional C^{++} builder to provide a new innovative tool for estimating evapotranspiration of applied water (ET_{aw}), which is a seasonal estimate of the water requirement for evapotranspiration of a crop minus any water supplied by effective rainfall. SIMETAW software is designed to input 10 different input data files to make water balance calculations for crops without changing the model code. If unique situations require recoding, the source code has to be modified to facilitate this. SIMETAW runs on IBM PC compatible Pentium-equivalent or higher, 16MB RAM, Windows 95/98, NT 4.0, Windows 2000, Windows XP. It is available to the public on CD's. A Windows® help file for the program is being written to explain the various components of the program and help users how to use the program to determine ET_{aw} for a study area. In additions; it gives examples of data format used in input and output files. The program also contains a user's guide and a 10-page help sheet. To run, SIMETAW requires Windows Excel 97, Excel 2000, Excel XP, Word 97, and Word 2000 to display files generated by SIMETAW.